High Resolution Observations of Spicules with of Hinode/SOT

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Spicules

Spicule： hair-like jet features seen on the limb in optically thick chromospheric lines.

They are ubiquitous（provided mottles or fibrils are on-disk counter part features） but are mysterious in their origin, motion and evolution

Origin; hydrodynamic vs. magnetic

What mechanism drives it?

similarity to other jets

Motion: constant vel., parabolic, propagation of ionization front, etc.

Evolution: fade out after ascent, heating up to coronal T?,

correspondence with UV spicules, down flow in EUV,

mass supply to the corona and solar wind

Observation and Data Process

- Solar spicules on the limb were observed with a broad-band filtergraph (BFI) of the Solar Optical Telescope (SOT) aboard Hinode, in which wavelength pass band is centered at Ca II H 396.8 nm with a pass band of 0.3 nm
- The Ca II H broad-band filtergraph enable us to virtually observe all the spicules within large line-of-sight velocities of up to +/-100 km sec-1.
- The observation can be performed in continuous fashion over hours with a diffraction limited spatial resolution (0.2 arcsec or 150 km on the Sun) of the 50-cm aperture telescope and with much reduced scattered light from the solar bright disk even in this short wavelength.
- Cadence: 5 – 8 sec

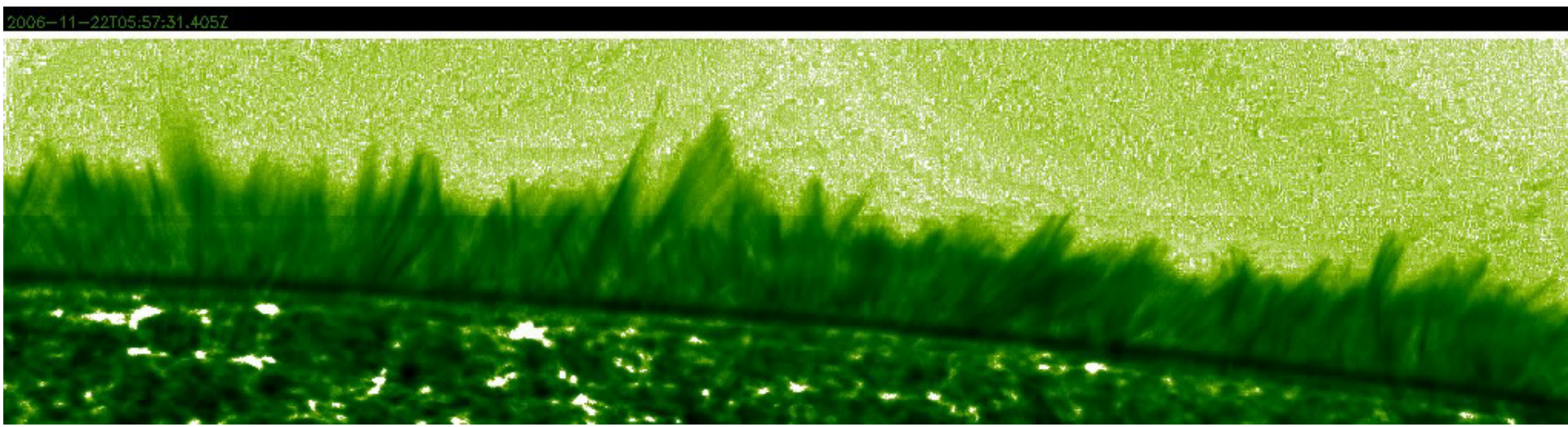
Data Process

The spicules on the limb are very faint on contrast to the disk brightness. To enhance the visibility of the off-limb faint features as well as features inside the disk at the same time, we subtract a background which consists of minimum brightness in the time series data set at a pixel and is shifted entirely by ten pixels (0.54 arcsec) toward the disk center. This is a kind of un-sharp masking method but has a merit giving rise to less unrealistic sharpened structure than usual ones, because the background is monotonic in the off-limb except at the very limb.

Spicule Movie in West Limb (22 Nov 2006)

tall spicules: expand and move laterally with ascent and then descend

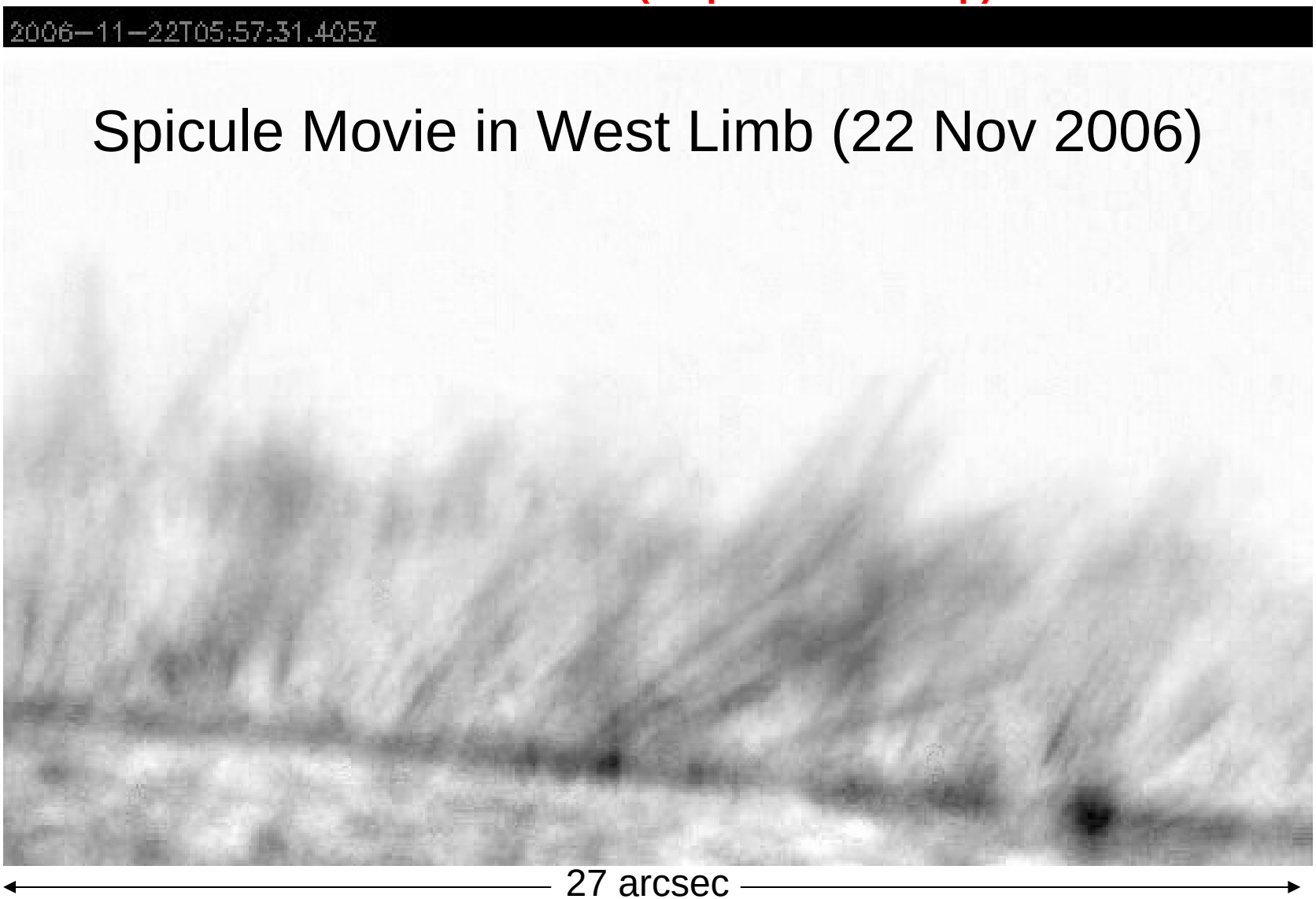
#The motion looks **twisted Flux tube gets untangled**



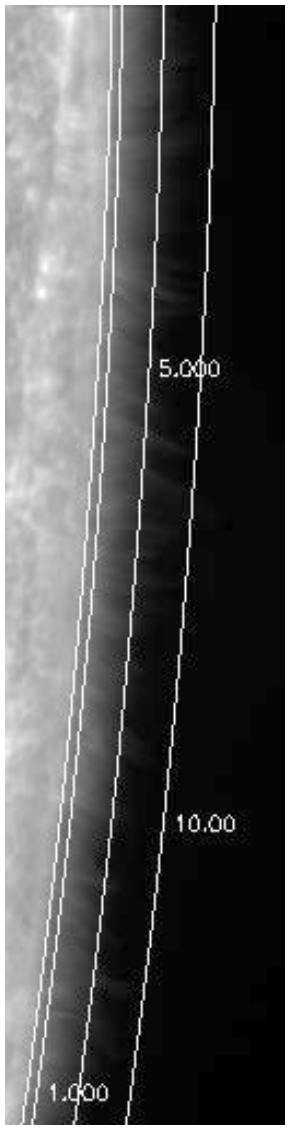
Closer look-up

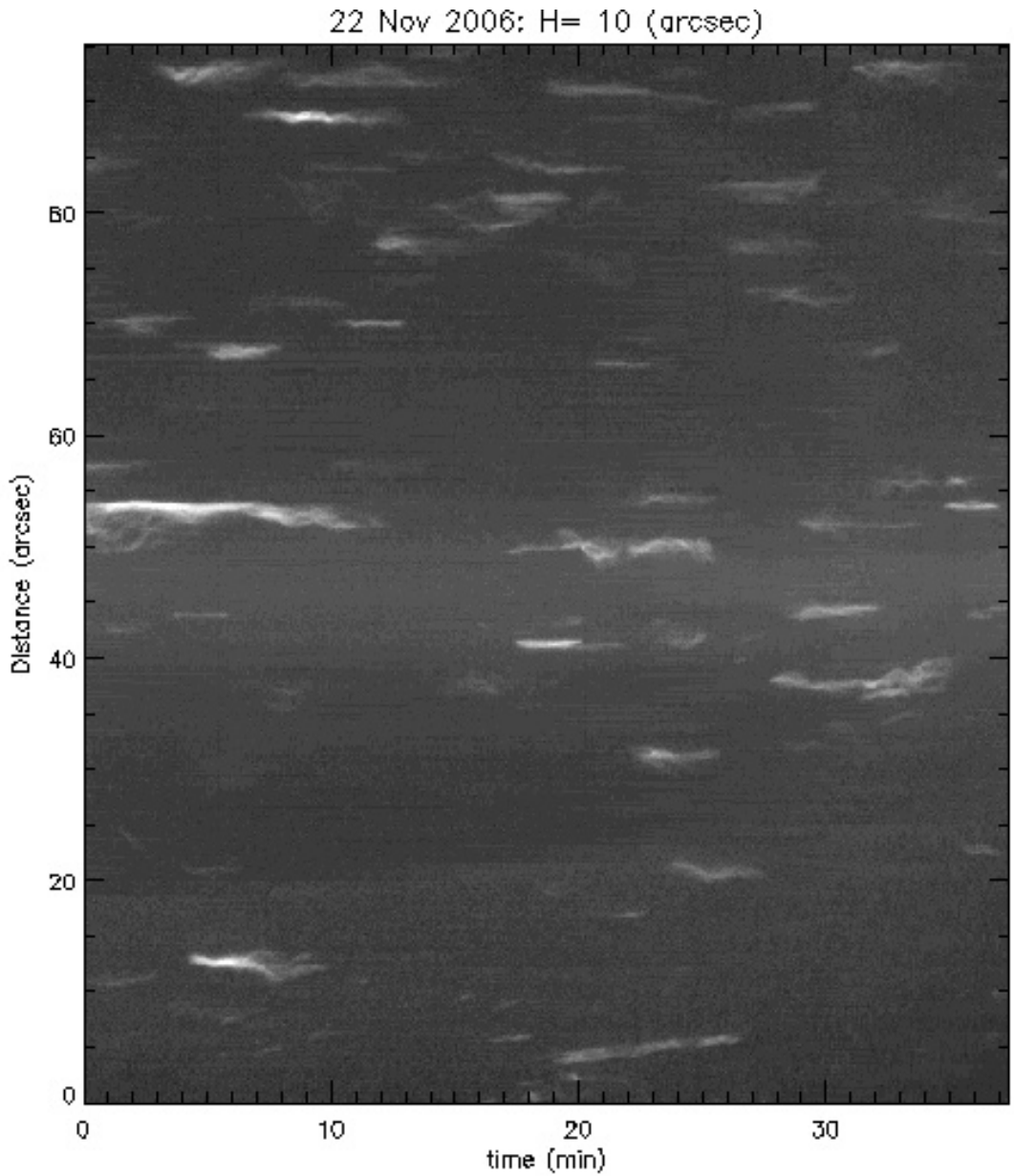
#Fine-scale multi thread structure (micro-jet?)
#Lateral or helical motion
#upward motion dominant

 # thin structure (no prominent loop) at root



Spicules in West Limb (22 Nov 2006): time slice at off-limb height of 10 arcsec



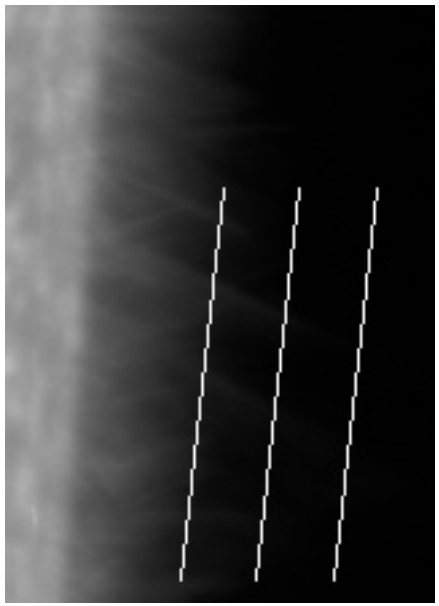


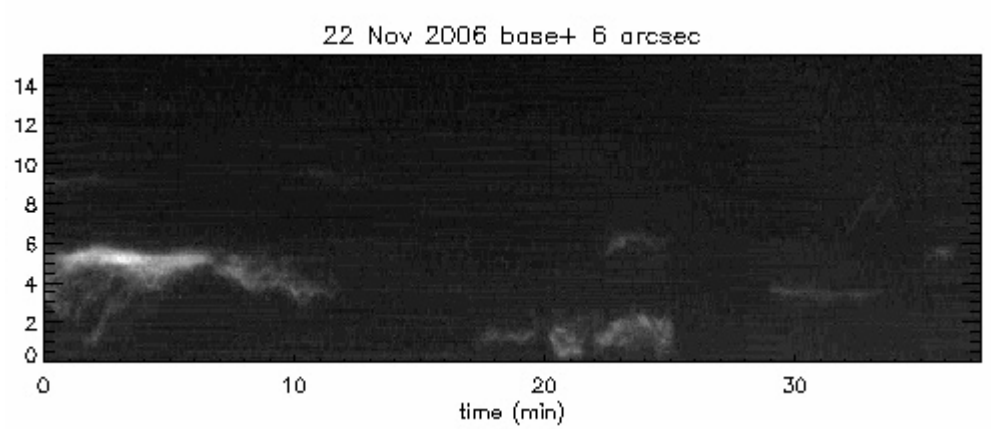
Lateral oscil. (or helical motion?) is prominent!

Period: 1-3 min

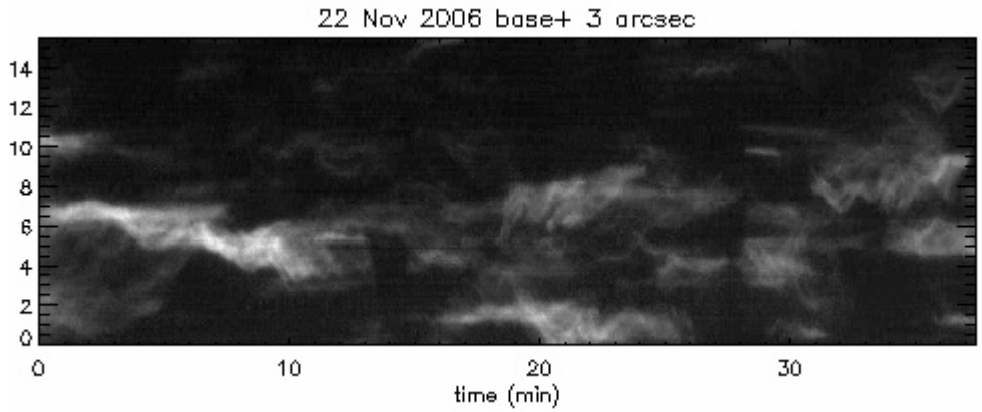
Twisted Flux tube gets untangled?

Hinode Dublin, 21 Aug.





H=11”



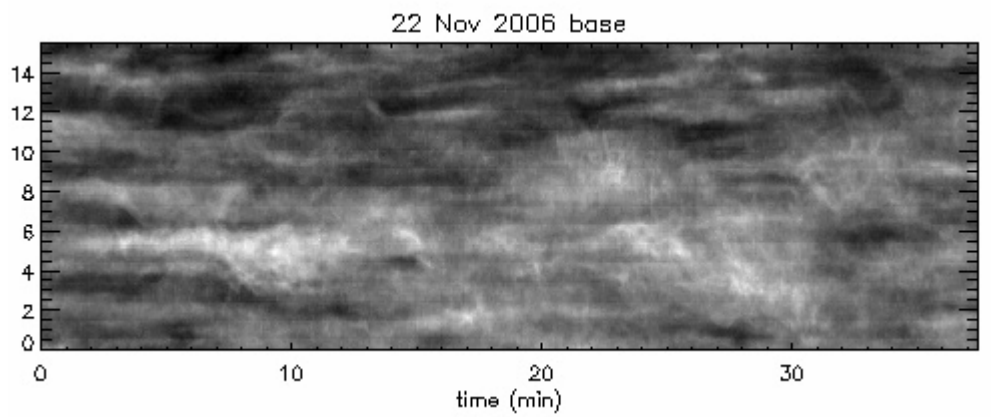
H=8”

Lateral oscillation

Amplitude： ～1”

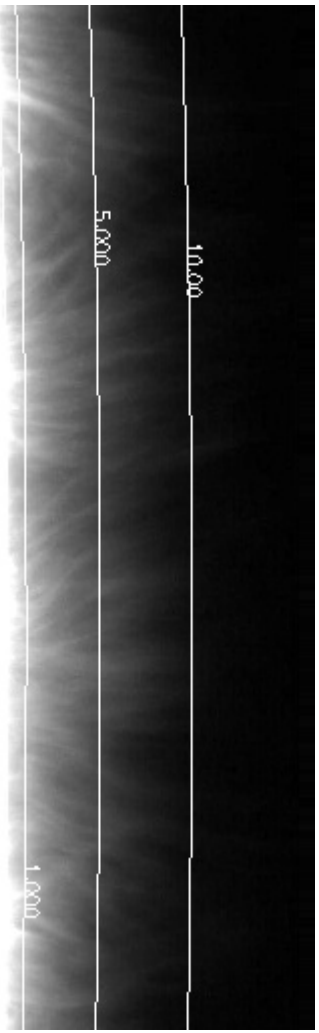
Period： 1-3min

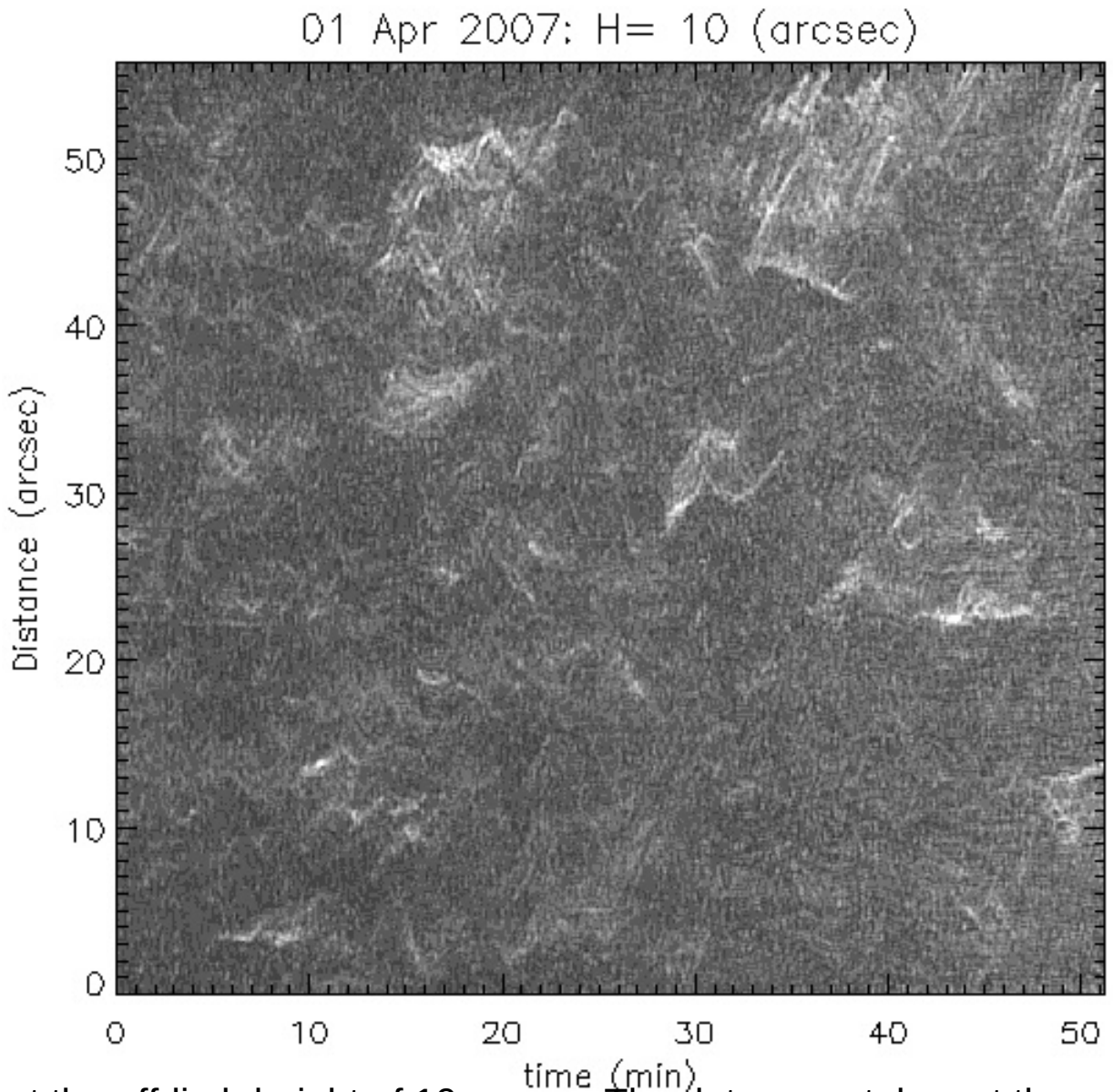
Velocity： ～15 - 20km/sec



H=5”

North Pole



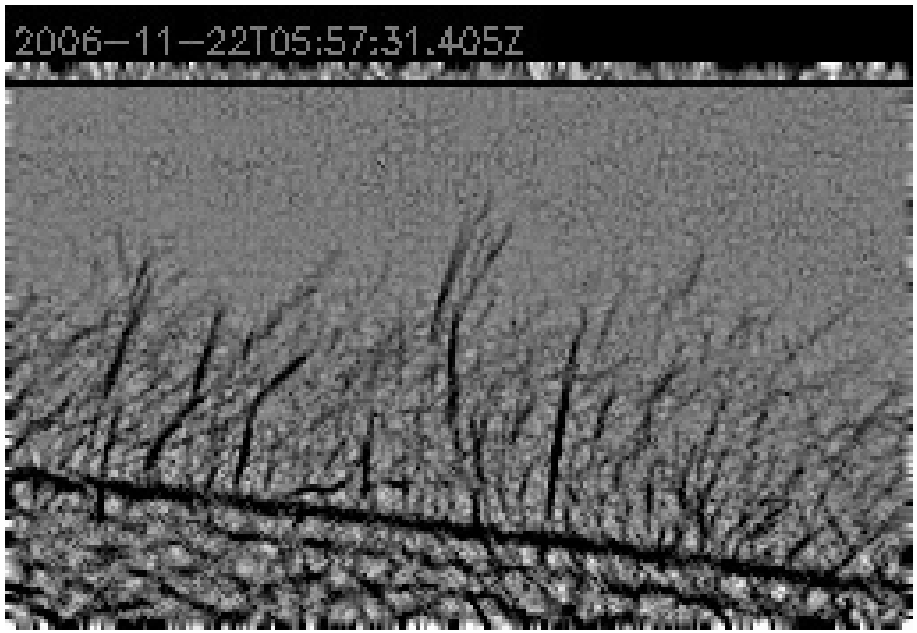


Time slice map along the limb at the off-limb height of 10 arcsec. The data were taken at the north pole on 1 Apr 2007. Lateral motion (excursion) and oscillation get prominent as the height goes up. The period of oscillation is 1 to 4 min, the amplitude is about 1 arcsec and maximum lateral velocity is about 15 -25 km/sec.

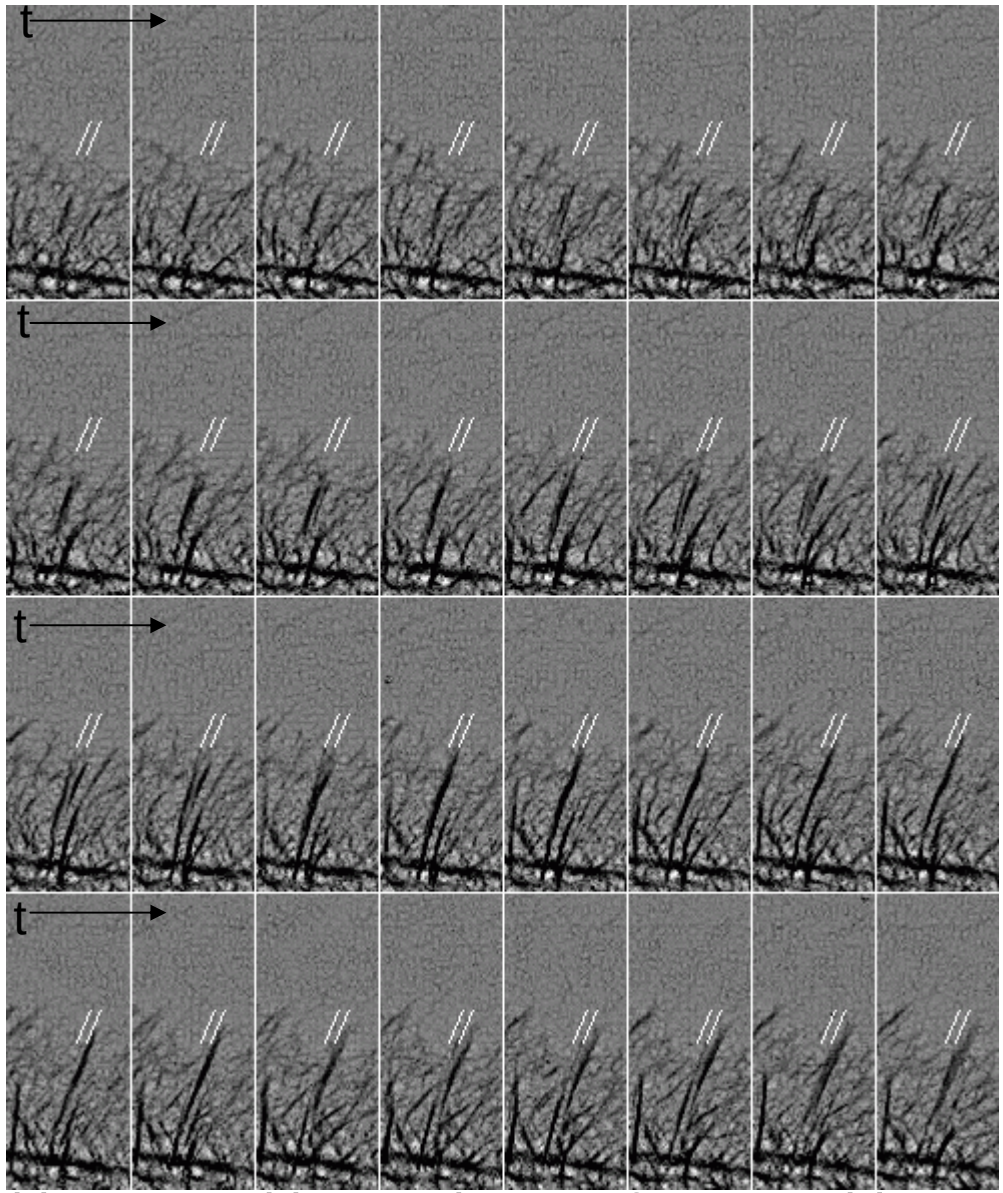
It was found that most spicules show up double thread structure during their evolution. This feature was already mentioned by Tanaka for disk mottles in high resolution H-alpha wing observation (1974) . Therefore it is likely that the spicule and disk mottles in quiet Sun have the same origin. New findings for the spicules are that the separation of the double threads change with time by the spinning as a whole body; repeating phases single and double threads.

Spinning double threads

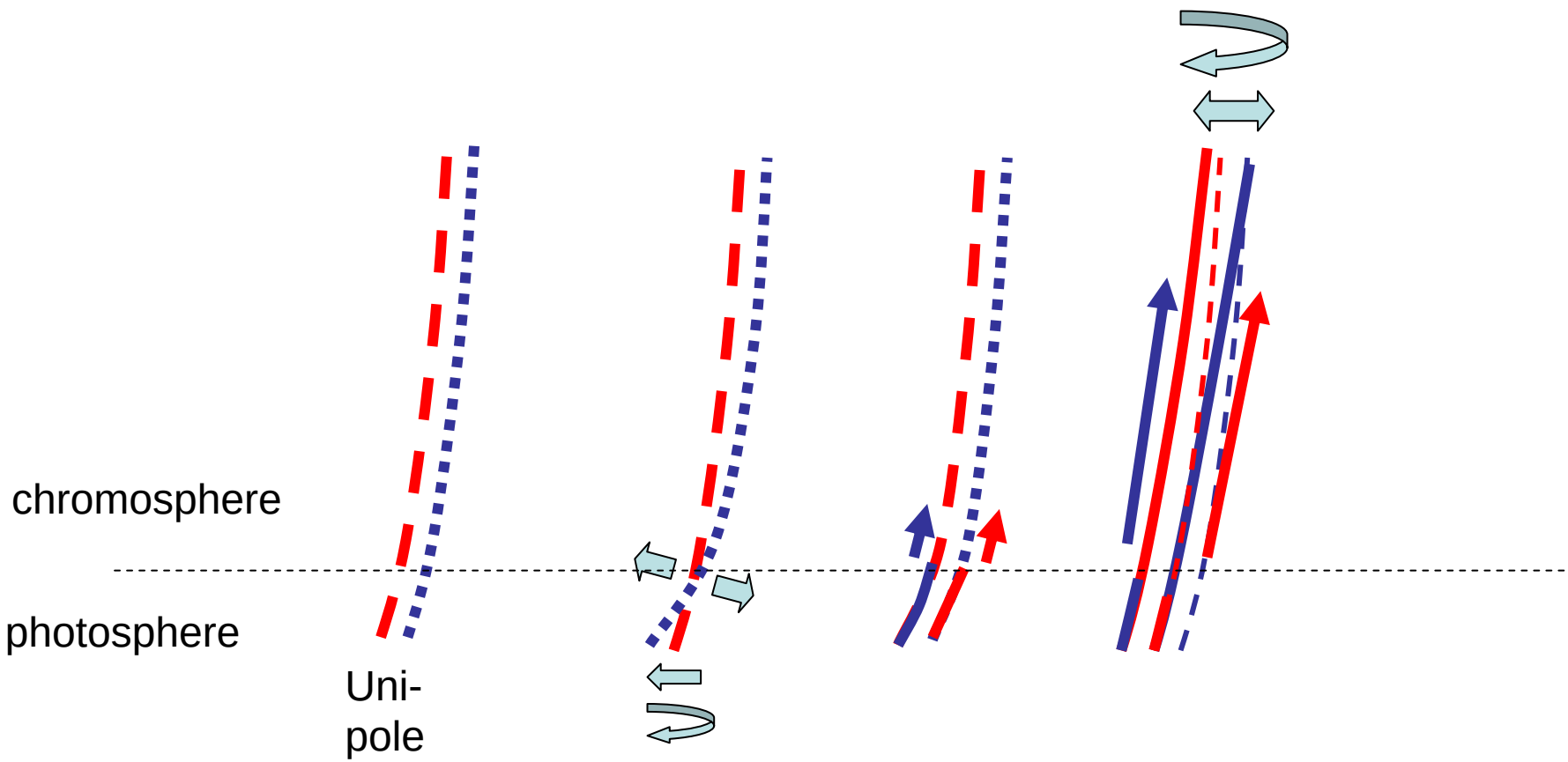
Data process: background subtraction and ‘madmax’ (Koutchmy & Koutchmy (1989)



Many double thread features



Sharpened images with a cadence of 5 sec. This series clearly show that the spicule of double threads (indicated by white lines) is spinning as a whole body (spin period: 1 - 1.5 min, v〜15 km/sec).



Speculative magnetic reconnection model to explain the double thread structure of spicule and following evolution (expansion thread separation, lateral motion and spinning as a whole body).

Summary

- High cadence observation with a Ca II H broadband filtergraph (passband of 0.3 nm) of the Solar Optical Telescope (SOT) aboard HINODE has revealed detailed dynamical nature of solar limb spicules.

- The spicules in Ca II H typically have double thread structure; each threads are a few tenth of arcsec wide.
It should be stressed that most spicules do not show a simple up-and-down motion along a rigid path line. They start with bright structure emanating from Ca II H bright region, get widen and diffused with time and ascent, showing expansion with lateral or even spinning motion.

- Small and short lived spicules tend to fade out after ascent.
(50 % spicules fade out after ascent, straw (Rutten), short lived upflow (Title 1967), EUV explosive events, etc.)

Summary (cont.)

- Double threads structure found for the spicule for the first time,which was already mentioned by Tanaka (1974) for disk mottles in quiet Sun, may indicates that the spiclues and disk mottles have the same origin.

- Owing to the double threads structure, the spinning of spicule as a whole body was confirmed, this feature was so far speculated with a tilt of spectral lines.

- The fine structure and lateral motion indicate that the spicules can be ejected by magnetic reconnection mechanism at foot like their sister jets such as macro-spicules and surges, although most spicules emanate from seemingly uni-polar magnetic region and the relevant magnetic reconnection must take place in unresolved spatial scale contrary to the larger-scale jets.

Driving mechanism whatever should explain large aspect ratio of spicule: length / width > 10 (5” / 0.5”)